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13. ABSTRACT (Maximum 200 words)  This is the final report that describes the option period for this contract. During this option, we participated in a competition between various vendors to generate the best digital target map for the proposed sensor. To the best of our knowledge, this sensor is a coherent radar with improved range resolution that enables it to detect fine elevation differences in the terrain and to compare them with a stored elevation signature of the area upon target approach. Although our algorithms are in their infancy, we accepted the challenge and will attempt to produce an appropriate elevation signature description using the data supplied.  A series of tools were created to exploit the DPPDB product and display the processing results. A subset of this toolset enables the viewing and exploitation of the correlation results that were generated. The toolset allows for investigation of various tuning parameters and settings to provide insight into the appropriate threshold values necessary to extract the desired features. This entire process is automated. After the thresholds are determined, the entire DEM was generated by the algorithms and stored on the computer. No human interaction was performed during its creation.				
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**SBIR PHASE I – TOPIC N00-004  
AUTO-CORRELATION OF ELEVATION DATA FROM DIGITAL  
STEREO IMAGERY**

**FINAL REPORT  
OPTION PERIOD**

**CDRL #003AC**

16 February 2000

Prepared Under:

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for

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## **RESULTS FROM 16/NOVEMBER/2000 - 16/FEBRUARY/2000**

### **Introduction**

This is the final report that describes the option period for this contract. During this option, we are being asked to participate in a competition between various vendors to generate the best digital target map for the proposed sensor. To the best of our knowledge, this sensor is a coherent radar with improved range resolution that enables it to detect fine elevation differences in the terrain and to compare them with a stored elevation signature of the area upon target approach. Although our algorithms are in their infancy, we accepted the challenge and will attempt to produce an appropriate elevation signature description using the data supplied.

### **Processing Results Description**

On the CD, you will find two tools entitled StereoViewer and MonoViewer. Their usage is described in Appendix A & B, respectively. They allow the operator to view the image with the overlay of the feature processing results. The image can be viewed and the result of the process will be overlaid in "red" and aligned with the image pixels that it matched. The image is a backdrop to demonstrate the process and describe its accuracy and time efficiency compared to traditional correlation approaches.

The time to generate this result shown and the accuracy of the detections were key considerations in the development of our approach. An important fact is that the sensor's image processor is sensitive to the data that it is asked to correlate upon. The feature result shown is consistent with the sensor's image map and will produce an optimal correlation from which the inertial navigation system can be updated.

The analysis performed on the imagery may create results in which too few detections or an inordinately large number of detections would be generated to pass on to the matching process. The result shown on the CD resulted from choosing thresholds in the pre-processing stage of the algorithm that resulted in an optimized set of matching points that rely upon strong edge boundaries within the image. It has been shown in several studies that the strong edges in an optical scene are, for the most part, also the strong edges in an IR or SAR scene.

If a regular grid is generated by interpolating the results shown, an inaccurate representation of the dominant targets in the scene will result. This generates a non-optimal match when the seeker attempts to correlate its detections against the grid presented to it. Also, each of these points generated by interpolation must be matched within the targeting seeker's image. This increases the processing requirements of the seeker processor and can degrade the overall match process by adding detections that must be equally weighted in the final navigation update for the targeting sensor while contributing little to the uniqueness of the match itself.

Each of these correlation results represent the x, y pixel location of the image pixel within the left and right stereo pair for a given feature such as a building rooftop or road boundary. By using the image – to – geodetic transformation (rational polynomial coefficient application in the case of DPPDB), the geodetic location (X, Y, & Z) can be provided to the targeting sensor with the full accuracy of the product from which it was extracted (DPPDB product accuracy if this source imagery is used). The process results in an optimized version of a Digital Elevation Model or DEM. The number of detections from which a match pixel can be generated is controlled by the Canny edge detection threshold logic. This process is also extremely efficient computationally since only those detections that were detected as strong edge detections are used in the matching process. We have also optimized both the Canny edge detection pre-processing and the correlation match geodetic feature extraction algorithms.

There are edges that are generated by shadows in the optical scene that may or may not exist in the targeting image; however, this fact is irrelevant because each of the detections that are shown in the map have an accurate X, Y, Z geodetic coordinate attached to them. They represent a physical geodetic location of the shadow on the ground.

### **Test Results**

A series of tools were created to exploit the DPPDB product and display the processing results. A subset of this toolset enables the viewing and exploitation of the correlation results that were generated. The toolset allows for investigation of various tuning parameters and settings to provide insight into the appropriate threshold values necessary to extract the desired features. All of the results from this imagery and subsequent test imagery are being supplied on a classified CD as an addendum to this final report.

After the imagery is extracted from the DPPDB segment, a preprocessing stage is performed on the imagery. This creates a template description of the pixels in the left stereo-pair image from which to drive the correlation processing in the right stereo-pair image. On the CD are all of the original image chips in TIFF format. With the StereoViewer or MonoViewer tool supplied on the CD, the user can investigate the performance of the algorithm and tune its results to generate the desired DEM for a particular sensor scenario.

The correlation processing looks in the right stereo-pair for corresponding matches to the template description in the stereo-pair. The current state of algorithm development does not always provide a one-to-one match. The possible results include finding a correct match, finding no match, and finding an incorrect match. Since we did not have access to the 'truth' data prior to this report, an accuracy assessment could only be conducted on a qualitative basis. For each area tested three sample areas were chosen to evaluate the algorithms performance. Two of the areas were representative of the entire scene results and the third area was selected as a worse case scenario. Whenever a match in the right stereo-pair correctly corresponds to the left stereo-pair template, the algorithm returns the position at the accuracy inherent to DPPDB. The next step in algorithm development will be to add a contextual processing step that will identify additional parameters in the left stereo-pair template that will be used to drive the correlation-processing algorithm.

The following test sites and their associated statistics are shown in Table I.

Source area	Terrain/Culture Type	Processing Time	Probability of success	Comments
			Total points/matches	
Baltimore,MD	High density urban	6 minutes	1) 157/153 97.5% 2) 140/140 100% 3) 193/173 89.6%	The algorithm results were excellent for this cloud covered scene
San Francisco, CA	High density urban	7 min	1) 147/144 98.0% 2) 181/179 98.9% 3) 133/100 75.2%	The algorithm performed well with the convergent stereo data within this imagery

Fort Polk, LA	Tree lines/no relief	6 minutes	1) 131/131 100% 2) 143/143 100% 3) 160/160 100%	This was a simple scene for this algorithm
Meling Orchard, CA	repetitive patterns	6 minutes	1) 163/163 100% 2) 198/198 100% 3) 202/183 90.6%	Another simple scene
Fort Benning, GA	Hills, gullies and airfield	7 minutes	1) 142/142 100% 2) 126/126 100% 3) 116/70 60.3%	Highly correlated terrain contours with shadowing in third sample
Oakland, CA	High density urban	6 minutes	1) 178/173 97.2% 2) 160/160 100% 4) 195/121 63.1%	Highly correlated building features with shadowing in third sample

An interesting result occurs if you load the left stereo-pair edge points into MonoViewer and then load the DEM post results into the same window. The result is shown in figure 1 and this gives an indication of the image positions within the image that mis-matched during the correlation process. The red pixels represent the points within the image that correctly matched to create stereo DEM posts. The black pixels are the edges that were detected in the left image; but which did not have a corresponding match in the right image.



Figure 1: Edge processing result overlaid with the “red” correlation match result

In closing, it should be noted that this entire process is automated. After the thresholds are determined, the entire DEM was generated by the algorithms and stored on the computer. No human interaction was performed during its creation.

#### **PROJECT STATUS**

No impact or significant change to the planned work schedule has occurred.

#### **RECOMMENDATIONS AND PROPOSALS**

None.

### Background

On the CD, you will find a tool entitled “StereoViewer”. This tool requires special graphics hardware and shuttered stereo-viewing glasses to enable the view to appear stereoscopic. It allows you to view the image with the overlay of the DEM feature processing results. The image can be viewed and the result of the process will be overlaid in “red” and aligned with the image pixels that it matched.

### Using StereoViewer

To use the StereoViewer program that is supplied on the CD, open the “Stereoviewer.exe” file on the CD by “double-clicking” on it. The image window will appear as shown in figure 1. The 3 sets of “arrow” keys are used to shift within the left image, right image, or both images in the pixel increments displayed. The “magnification” button will magnify or minify the contents of the viewing window. The first set of scroll arrows allows the user to shift the left image by an incremental amount shown in the text button box next to it. Similarly, the second set of arrows will have the effect of shifting the right image relative to the left. Either of these sets of arrow buttons allows the user to adjust the stereo baseline to enable the proper viewing of objects in the stereo scene with varying amounts of x-parallax. Since the stereo model is scaled to accommodate the viewing physics of a human’s binocular vision system, these adjustments are necessary. The 3<sup>rd</sup> set of arrow buttons is used to scroll within the stereo imagery and does not affect the parallax but allows the user to view different areas of the image on the screen.





Figure 1: Main viewer window

On the “file” menu use the file dialogue box of figure 2 will appear when “Open images...” is selected. Double-click on the “left.tif” file icon and then “double-click” on the “right.tif” image icon. It will take a few seconds to display both images in the main viewing window.

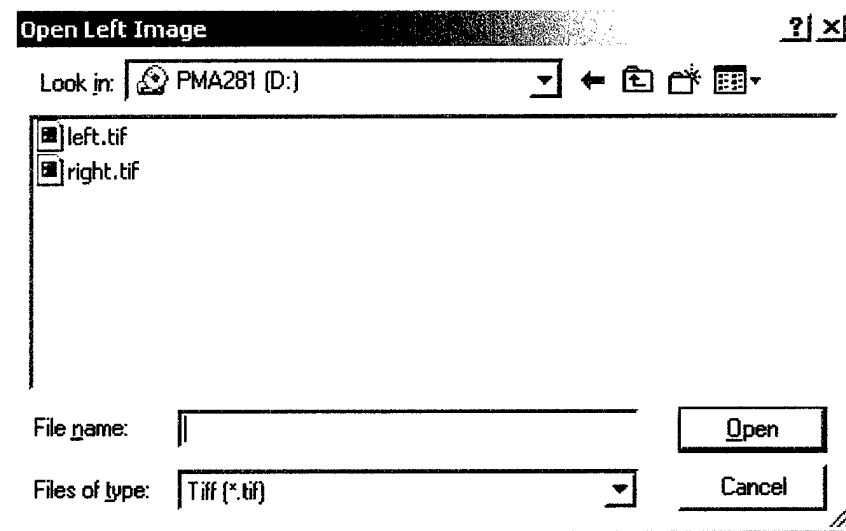


Figure 2: file-open dialogue box

Return to the “file” menu and select “Open DEM...” from the file menu. The file dialogue box of figure 3 will appear and select the “P21\_S50\_T50.dem” file by “double-clicking” on its icon.

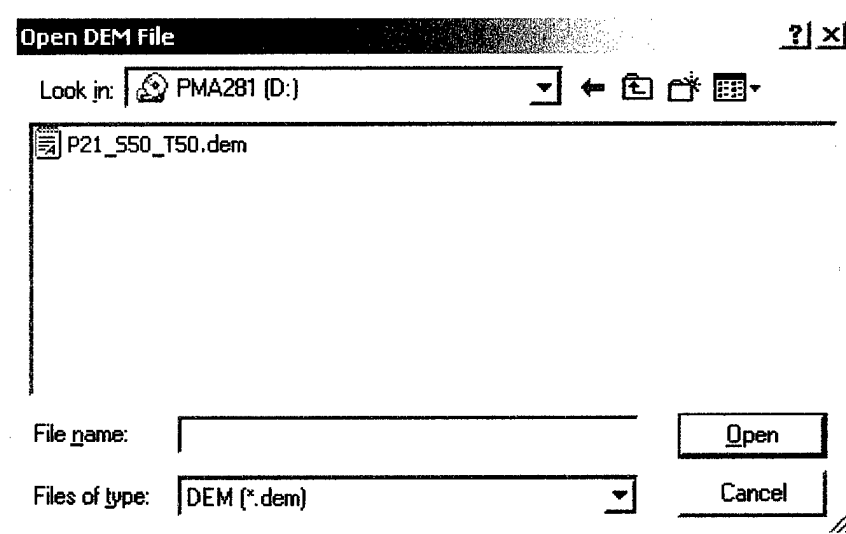


Figure 3: Feature dialogue box for the DEM

In Figure 4, the “red” shaded overlaid pixels represent the final result of the Canny preprocessing and Correlation matching operation. Each of these “red” pixels represent an object pixel in the left and right stereo-pair from which a highly accurate geo-location position (X, Y, & Z) exists.



Figure 4: Image overlaid with “red” correlation detections

For best viewing results, set the “magnification” to 50% and enlarge the Stereoview window to full-screen by “clicking” on the 2<sup>nd</sup> box button on the upper-right of the Stereoview window – this is like enlarging any window on a PC to full-screen. With the stereo-glasses on, scroll through the image by using the 3<sup>rd</sup> set of scroll arrows from the left-side of the main window in the tool, this scrolls both the left and right images of the stereo-pair in unison ensuring that the parallax does not change.

The geo-coded location of the current cursor is shown at the bottom of the window in real-time. If you desire to measure the height of a building or structure, scroll to it with the cursor and use the “middle” mouse button to lower the cursor and the “right” mouse button to raise the cursor to the proper height of the building. The height value at the bottom of the screen will represent the current height of the cursor and thus the object.

## APPENDIX B – MonoViewer Application Notes

### Using MonoViewer

To use the MonoViewer program that is supplied on the CD, open the “Monoviewer.exe” file on the CD by “double-clicking” on it. The image window will appear as shown in figure 1. The “arrow” keys are used to scroll within the image in pixel increments. To change the scroll increment, “click” on the “scroll-increment” button and select from one of the values (i.e. 1, 10, 100, 128, 256, 512, or 1024).



Figure 1: Main viewer window

On the “file” menu, select the “open” button and the file dialogue box of figure 2 will appear. Double-click on the “left.tif” file icon and the image will appear in the main window.

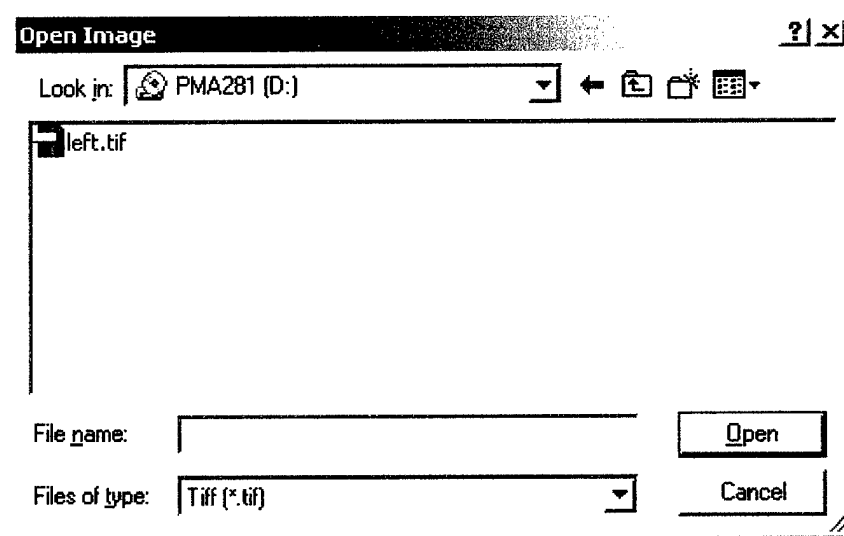


Figure 2: file-open dialogue box

Return to the “file” menu and select “Open DEM” from the file menu. The file dialogue box of figure 3 will appear and select the “left.dem” file by “double-clicking” on its icon.

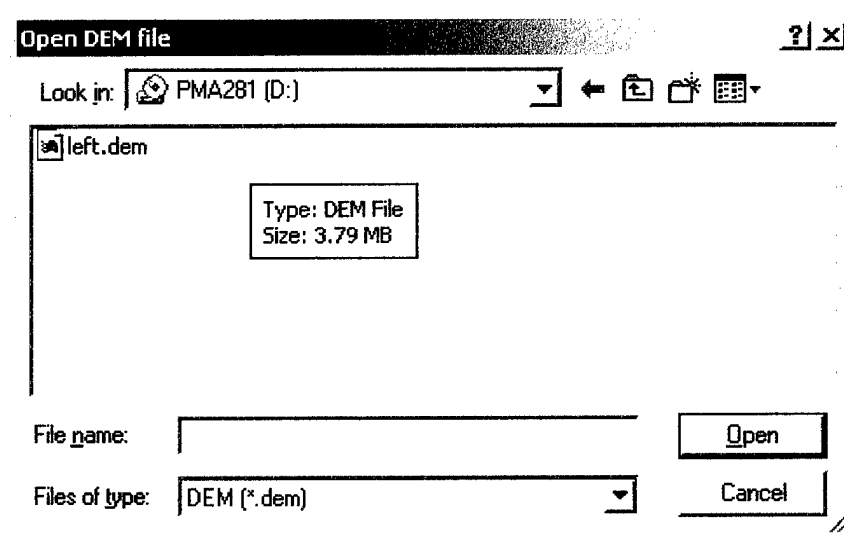


Figure 3: Feature dialogue box for the DEM

In figure 4, the “red” shaded overlaid pixels represent the final result of the Canny preprocessing and Correlation matching operation. Each of these “red” pixels represent an object pixel in the left and right stereo-pair from which a highly accurate geo-location position (X, Y, & Z) can potentially exist. Each of these edge points is used to direct the feature-based correlation algorithm to the area in the right stereo-pair from which to initiate a search for the correct stereo matching pixel.

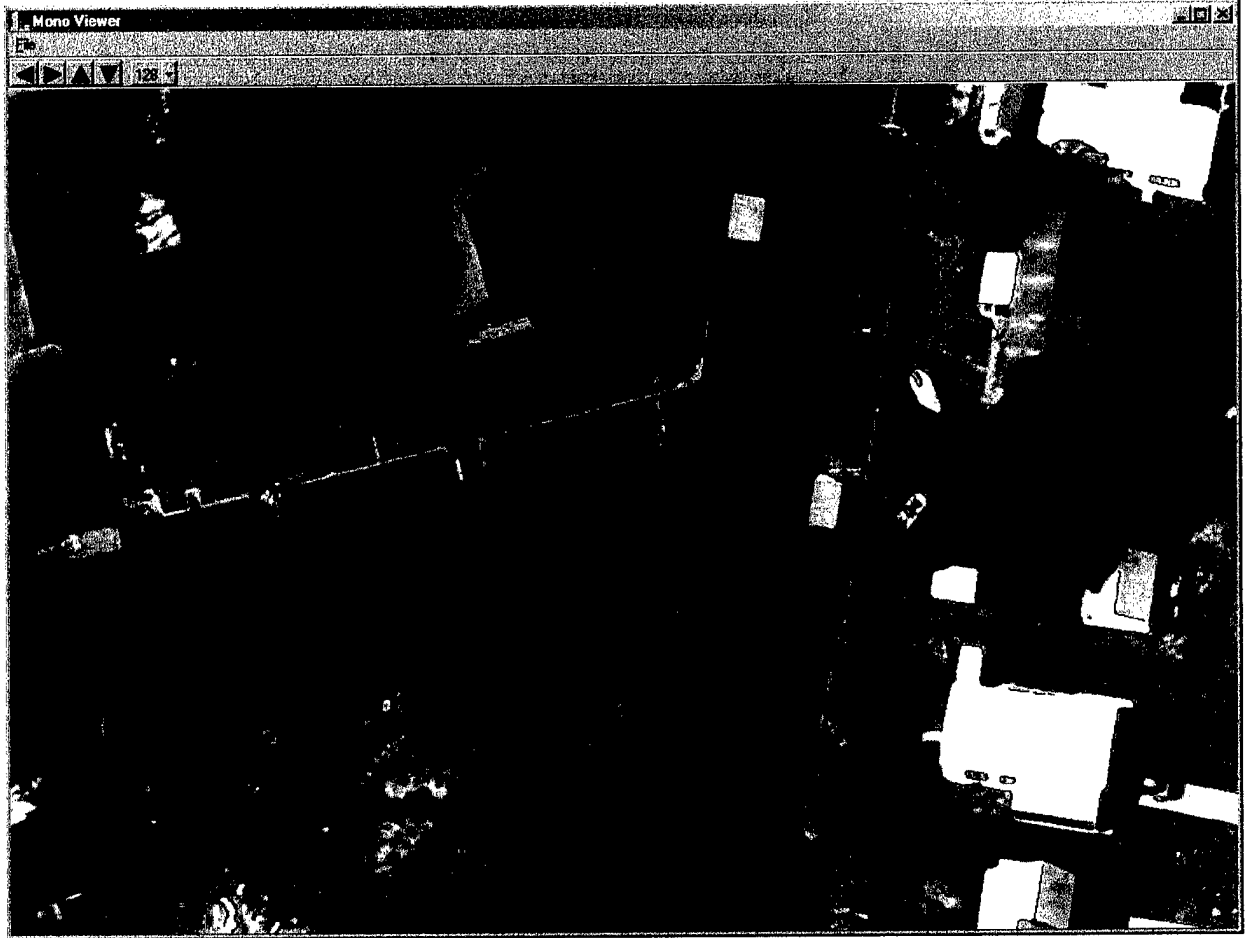


Figure 4: Left Stereo-pair image overlaid with “red” correlation detections